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(54) **LENS ACTUATOR**

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(51) **Int. Cl.**

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G02B 7/04	(2006.01)
G03B 3/10	(2006.01)
G03B 5/00	(2006.01)

(52) **U.S. Cl.**

CPC ***G02B 27/646*** (2013.01); ***G02B 7/04*** (2013.01); ***G03B 3/10*** (2013.01); ***G03B 5/00*** (2013.01)

(58) **Field of Classification Search**

CPC G02B 27/646; G02B 27/64; G02B 7/04; G02B 7/09

See application file for complete search history.

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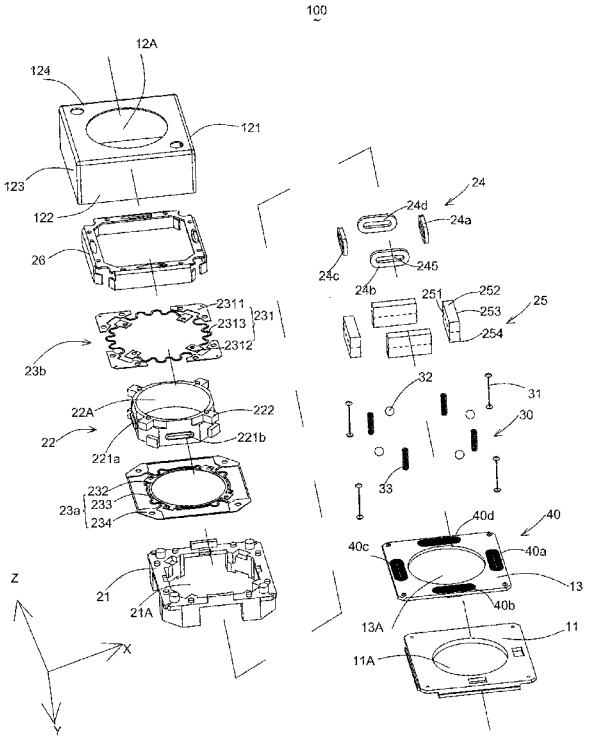
(57) **ABSTRACT**

A lens actuator is disclosed in the present invention. The lens actuator includes a movable unit including a carrier defining an optical axis, a plurality of focusing coils surrounding the carrier and spaced with each other, each wound around an axis perpendicular to the optical axis, fixed on an outer surface of the carrier, a plurality of magnets each opposite to one of the focusing coils in a direction perpendicular to the optical axis direction, and a holder fixing the magnets; a plurality of shake correction coils each disposed below one of the magnets and opposite to the magnet in the optical axis direction; a base fixing the shake correction coils; and wires connecting the movable unit to the base.

20 Claims, 5 Drawing Sheets



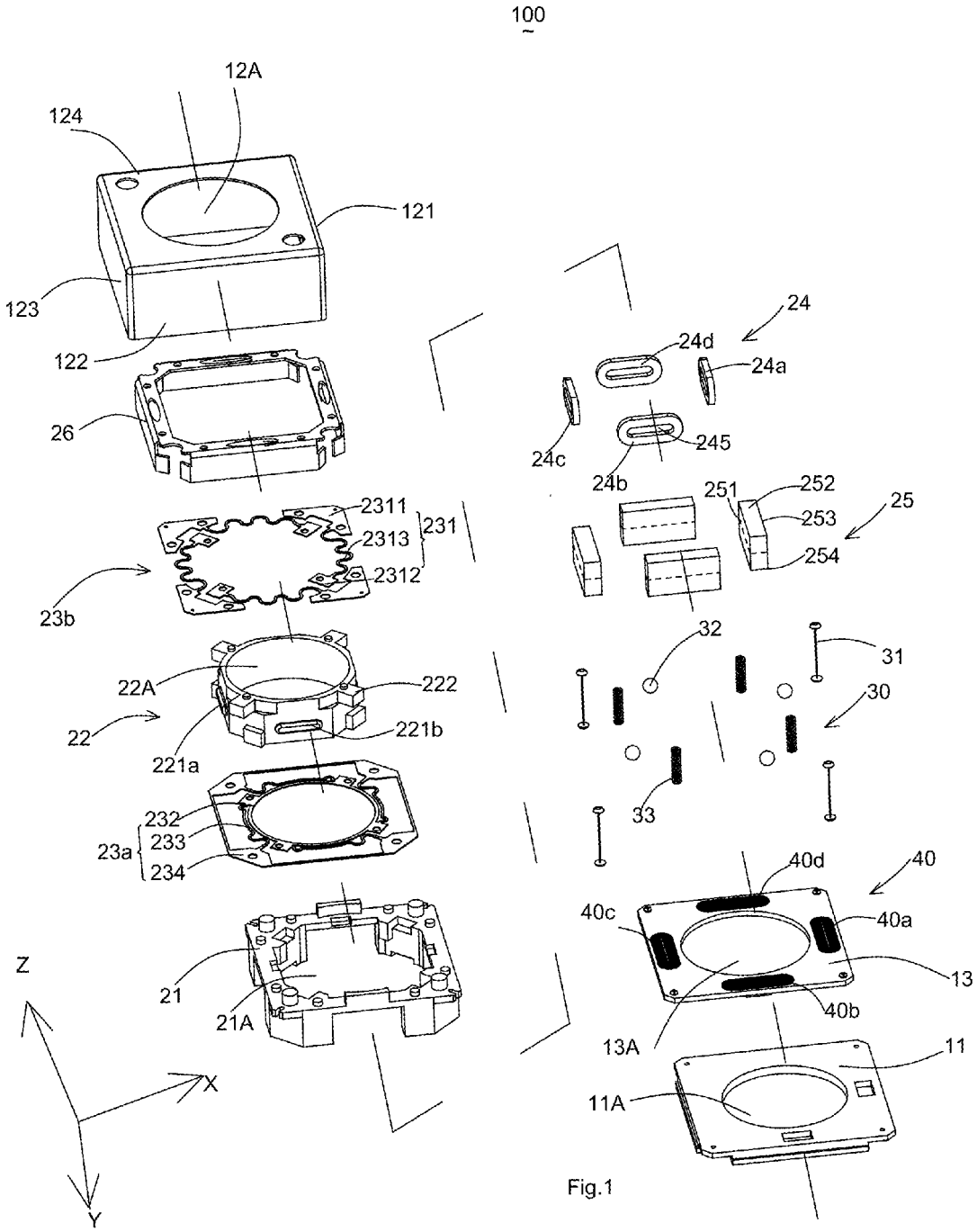

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Fig.1

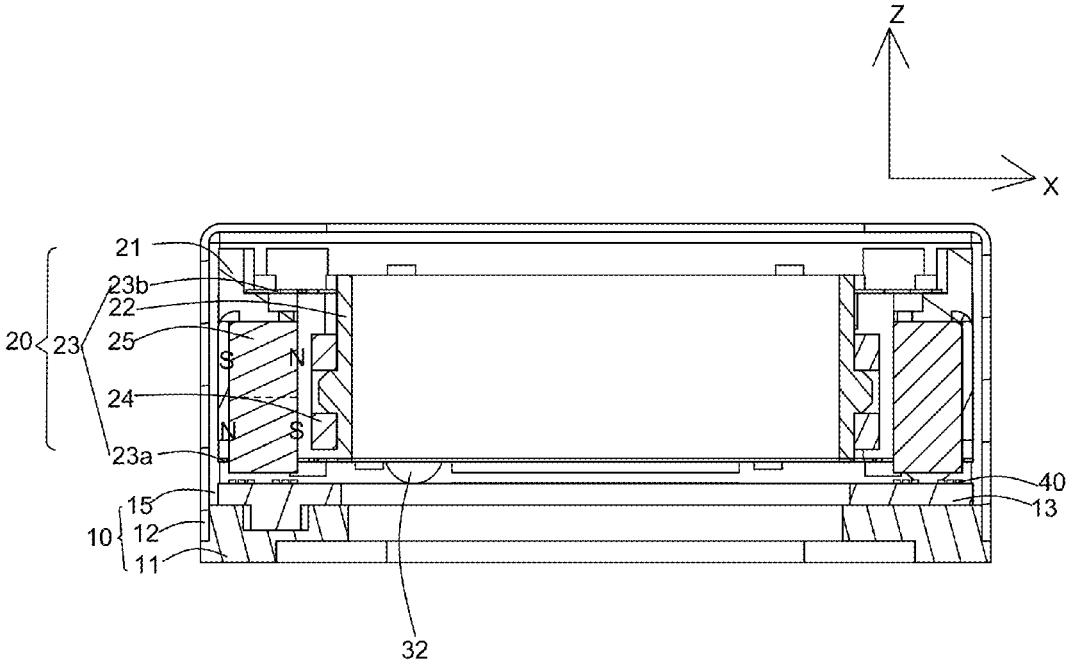

Fig.2

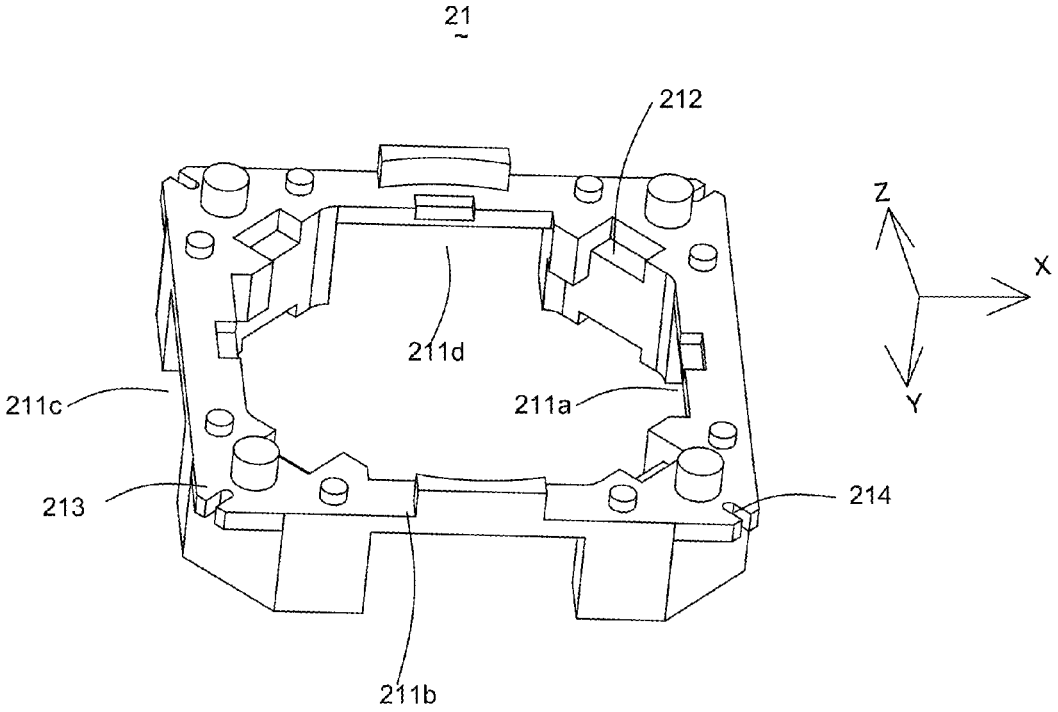
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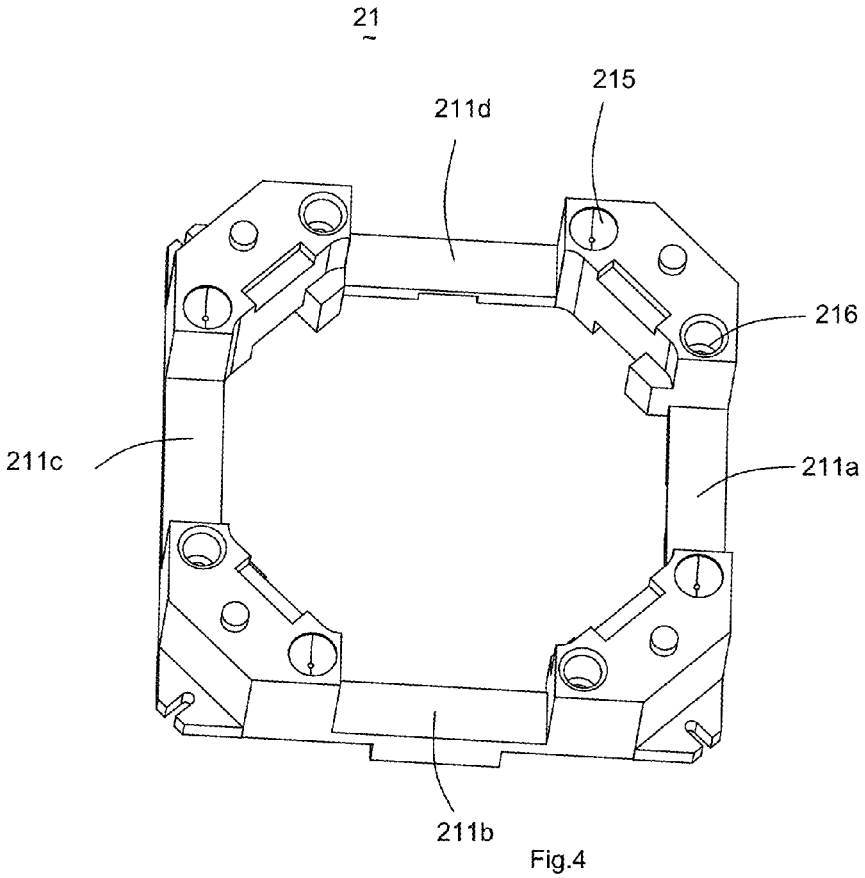
Fig.3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211b

Fig.4

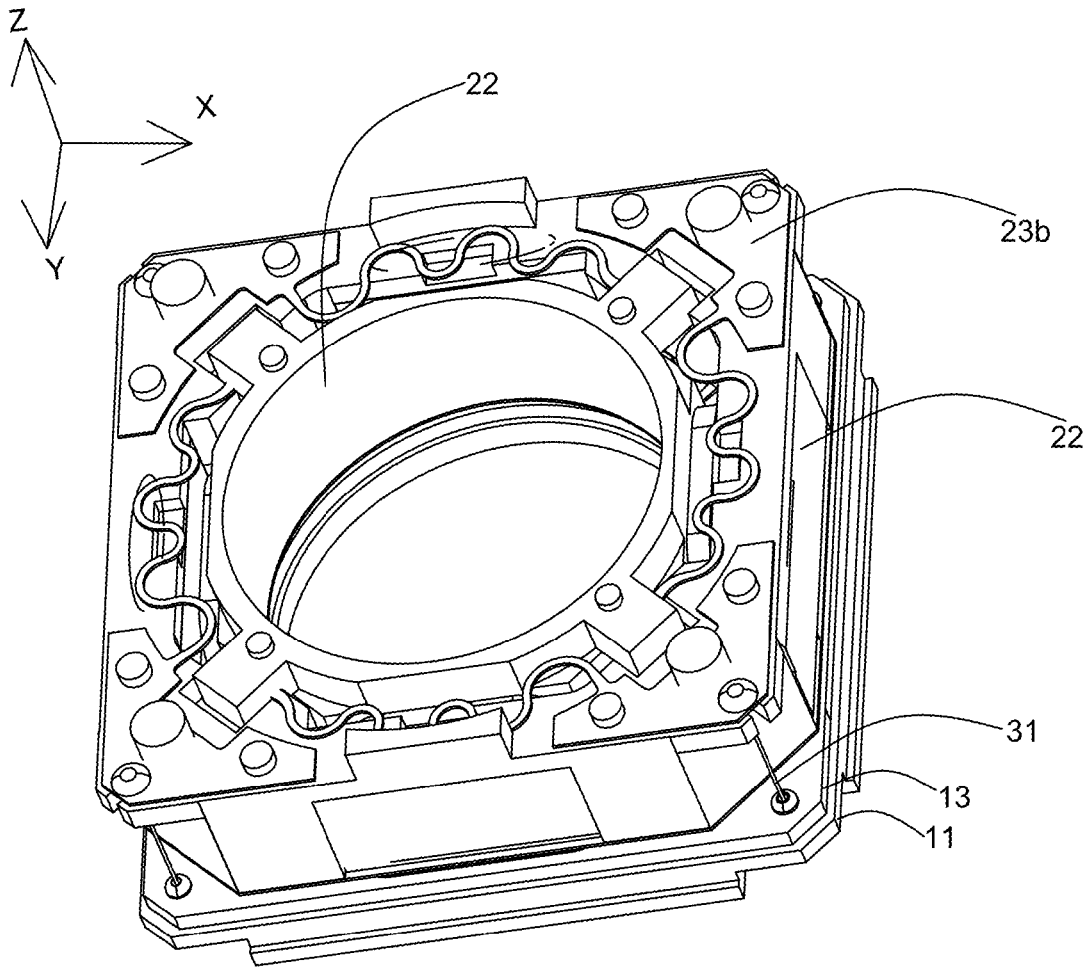

Fig.5

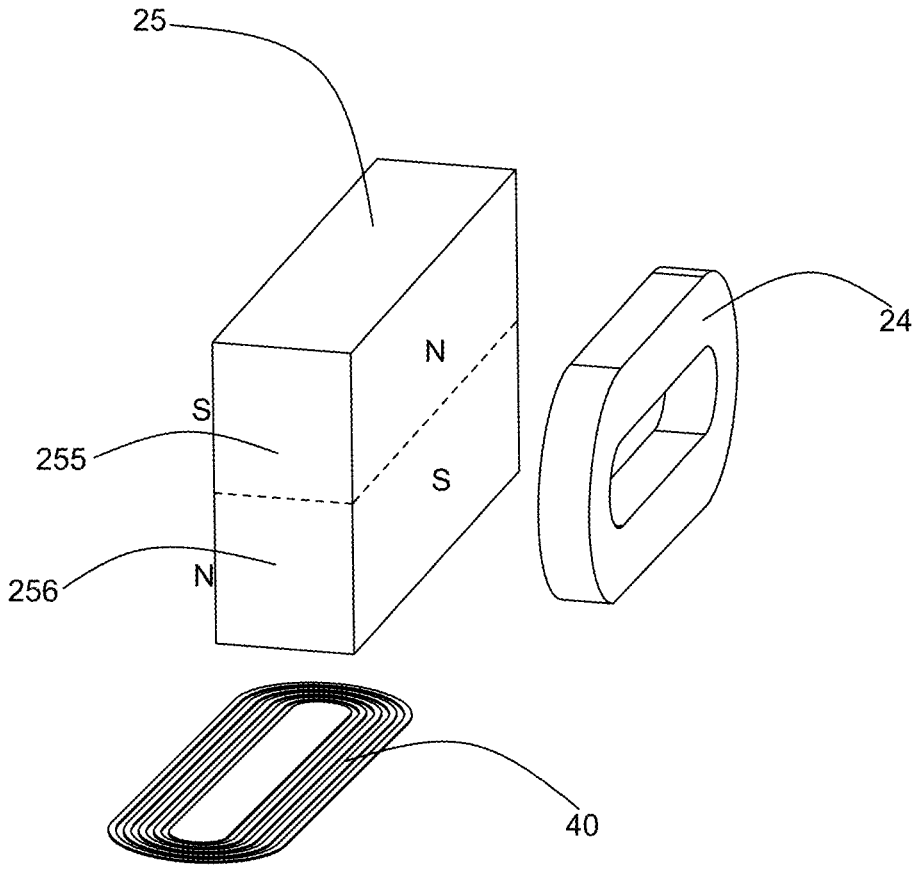

Fig.6

LENS ACTUATOR

FIELD OF THE INVENTION

The present disclosure generally relates to the art of driving apparatus, and more particularly to a lens actuator with optical image-stabilization (OIS) function.

DESCRIPTION OF RELATED ARTS

With the development of camera technologies, lens actuators are widely used in various digital devices equipped with cameras, like cell phones, video cameras, laptop computers and so on.

A lens actuator used in a digital device usually includes a lens holder, a lens disposed in the lens holder, a coil wound around the lens holder and a stationary magnet separated from the coil and interacted with the coil for generating an electromagnetic force for driving the coil together with the lens to move approaching or away along an optical axis. However, shake of the digital device occurs easily due to hand-held shooting during the photographing process, which directly causes image blur.

Therefore, an improved lens actuator is provided in the present disclosure to solve the problem mentioned above.

BRIEF DESCRIPTION OF THE DRAWINGS

Many aspects of the embodiment can be better understood with reference to the following drawings. The components in the drawings are not necessarily drawn to scale, the emphasis instead being placed upon clearly illustrating the principles of the present disclosure. Moreover, in the drawings, like reference numerals designate corresponding parts throughout the several views.

FIG. **1** is an exploded view of a lens actuator according to an exemplary embodiment of the present disclosure.

FIG. **2** is a cross-sectional view of the lens actuator in FIG. **1**.

FIG. **3** is an illustrative isometric view of a magnet holder of the lens actuator in FIG. **1**.

FIG. **4** is also an illustrative isometric view of the magnet holder, but from another aspect.

FIG. **5** is an assemble view of an assembly of a movable unit, a printed circuit board, and a base of the lens actuator in FIG. **1**.

FIG. **6** shows relative position relationship between a focusing coil, a magnet and a shake correction coil of the lens actuator in FIG. **1**.

DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENT

While the invention is susceptible of embodiments in many different forms, there is shown in the drawings and will herein be described in detail embodiment of the invention with the understanding that the present disclosure is to be considered as an exemplification of the principles of the invention and is not intended to limit the broad aspect of the invention to the embodiment illustrated.

Referring to FIGS. **1-2**, a lens actuator **100** according to the exemplary embodiment of the present disclosure is mounted to a mobile terminal such as a camera-equipped cellular mobile phone which is enable automatic focusing (AF), a smart phone, a notebook personal computer, a tablet-type personal computer, a mobile-type game machine, a Web camera, a vehicle-mounted camera, or the like.

The lens actuator **100** includes a housing **10** having a base **11**, a cover **12** assembled with the base **11** for forming a receiving space **15**, a movable unit **20** received in the receiving space **15** and movably mounted on the base **11**, and a plurality of wires **31** connected the movable unit **20** to the base **11**. The movable unit **20** defines an optical axis.

The cover **12** has a rectangular box shape that includes a first round hole **12**A in the center. The base **11** has a rectangular plate shape that includes a second round hole **11**A in the center. The housing **10** further includes a printed circuit board **13** fixed on the base **11** by adhesive, gluing or the like. The printed circuit board **13** has a rectangular plate shape that has a third round hole **13**A in the center. The cover **12** and the base **11** are made of nonmagnetic material, such as aluminum and nickel-silver alloy.

A coordinate system (X, Y, Z) is defined. The optical axis is referred as Z axis, and an upper direction of the optical axis is hereafter referred as a forward direction +Z (+Z side). When viewed from the +Z side, the four sides of the cover **12** are denoted respectively by **121**, **122**,**123**,**124** in a clockwise direction. The direction from the side **123** toward the side **121** is designated as a forward direction of the X axis (+X side); the direction from the side **124** toward the side **122** is designated as a forward direction of the Y axis (+Y side). The X axis and Y axis are orthogonal to the optical axis (Z axis) and perpendicular to each other.

The movable unit **20** includes a magnet holder **21** having a receiving hole, a spring plate connected with the magnet holder **21**, a lens holder **22** elastically suspended in the receiving hole by the spring plate, a plurality of focusing coils **24** fixed on the lens holder **22**, a plurality of magnets **25** each facing one of the focusing coils **24** and fixed on the magnet holder **21**, and a magnetic conduction member **26** attached on outer surfaces of the magnets **25** for effectively conducting magnetic fluxes.

Referring to FIGS. **3-6** and FIG. **1**, the magnet holder **21** is made of insulating resin, such as polycarbonate containing glass, and has a rectangular box shape that has a square hole **21**A in the center. Such square hole **21**A serves as the receiving hole. The magnet holder **21** has a first receiving groove **211***a*, a second receiving groove **211***b*, a third receiving groove **211***c*, and a fourth receiving groove **211***d*, which are formed on four sidewalls thereof respectively for receiving the magnets **25**. The first and third receiving grooves **211***a*, **211***c* are arranged on the +X side portion and the −X side portion of sidewalls of the magnet holder **21**. The second and fourth receiving grooves **211***b*, **211***d* are arranged on the +Y side portion and the −Y side portion of sidewalls of the magnet holder **21**. Four holder-side limbs **213** overhanging on four corners are provided on a top surface of the magnet holder **21**. Four holder-side latches **214** that constitute a U-shape groove are provided in the holder-side limbs **213** respectively. Four accommodating grooves **212** are formed on an inner surface of the magnet holder **21** and disposed in four corners of the magnet holder **21** for receiving the lens holder **22**. At least three mounting grooves **215** or blind holes **216** are formed on a bottom surface of the magnet holder **21**. In this embodiment, four mounting grooves **215** or/and blind holes **216** are formed on the bottom surface of the magnet holder **21** and disposed in four corners of the magnet holder **21** respectively.

The spring plate **23** includes an upper spring plate **23***b* and a lower spring plate **23***a* connected to an upper end and a lower end of the lens holder **22** respectively along the optical axis Z. The upper spring plate **23***b* is a conductive-metal plate spring, which includes four separated spring element **231** arranged in a clockwise direction to form a spring ring to

support the lens holder **22**. Each spring element **231** includes a first connecting portion **2312** connected with the lens holder **22**, a second connecting portion **2311** fixed on the magnet holder **21**, and an elastic arm **2313** connected between the first and second connecting portions **2312**, **2311**. The lower spring plate **23***a* is a conductive-metal plate spring, which includes an outer peripheral portion **234** connected with the magnet holder **21**, an inner periphery portion **232** connected with the lens holder **22** and a plurality of meandering springs **233** connected between the inner periphery portion **232** and the outer periphery portion **234**.

The lens holder **22** is made of insulating resin, such as polycarbonate containing glass, and has an octagon box shape that has a fourth round hole **22**A in the center for fixing lens (not shown). A screw thread may be included inside the fourth round hole **22**A for fixing the lens to the lens holder **22** firmly. The lens holder **22** has a pair of first projections **221***a* and a pair of second projections **221***b*. All of the projections **221***a*, **221***b* are protruding toward the magnet holder **21** from the outer surface of the lens holder **22**, surrounding the lens holder **22** and spaced with each other. The two first projections **221***a* are opposite to the first and third receiving grooves **211***a*, **211***c* in the X axis direction, respectively. The two second projections **221***b* are opposite to the second and fourth receiving grooves **211***b*, **211***d* in the Y axis direction, respectively. The number of the projections is not limited to this, which may be varied according to the actual requirement. Four protruding parts **222** are formed on a top end of the lens holder **22** and each corresponding to one of the accommodating grooves **212** of the magnet holder **21** for connecting to the magnet holder **21**. When assembled, the protruding part **222** is connected with the first connecting portion **2311** of the upper spring plate **23***b* by screw tread connection, and then both of the protruding part **222** and the first connecting portion **2311** are received in the accommodating groove **212** for connecting to the magnet holder **21**. The fourth round hole **22**A, first round hole **12**A, third round hole **13**A, second round hole **11**A are continuously made to form a through hole from the upper surface to the lower surface of the lens actuator **100**.

The focusing coils **24** includes a first focusing coils **24***a*, a second focusing coil **24***b*, a third focusing coil **24***c*, and a fourth focusing coil **24***d*, each of the focusing coils attached on the outer surface of the lens holder **22** by fixed on the first through fourth projections **221** respectively. The first and third focusing coils **24***a*, **24***c* wind around the X axis and are fixed on the two first projections **221***a* respectively. The second and fourth focusing coils **24***b*, **24***d* wind around the Y axis and are fixed on the two second projections **221***b* respectively. In this embodiment, all of the focusing coils **24** have a hole **245** in the center for receiving the projections **221**.

The magnets **25** are fixed on the magnet holder **21** by receiving in the receiving grooves **211***a*, **211***b*, **211***c*, **211***d* thereof. Each magnet **25** faces corresponding focusing coil **24** with a space therebetween for interacting with the focusing coil **24** to generate electromagnetic force to move the lens holder in the optical axis direction relative to the magnet holder. Each magnet **25** has a rectangular solid shape and includes an inner surface **251** facing one focusing coil **24**, an outer surface **253** opposite to the inner surface **251**, a bottom surface **254** facing the base **11** and a top surface **252** opposite to the bottom surface **254**. In this embodiment, each magnet **25** is divided into a first half part **255** and a second half part **256**. The first and second half parts **255**, **256** are magnetized such that magnetic poles on inner surfaces of the first and second half parts **255**, **256** differ from each other, and such that magnetic poles on outer surfaces of the first and second half parts **255**,**256** also differ from each other. For example, the inner surface of the first half part **255** is magnetized into a N-pole while the outer surface thereof is magnetized into a S-pole; and the inner surface of the second half part **256** is magnetized into a S-pole while the outer surface thereof is magnetized into a N-pole. Alternatively, the magnet **25** may include two separated permanent magnet which are magnetized in different directions.

The shake correction coils **40** includes a first shake correction coil **40***a*, a second shake correction coil **40***b*, a third shake correction coil **40***c*, and a fourth shake correction coil **40***d*, each of the shake correction coils fixed on the printed circuit board **13**, below the magnets **25** and face the lower surfaces **254** of the magnets **25** with a space therebetween. The first and third shake correction coils **40***a*, **40***c* are disposed on the +X side portion and the −X side portion of the printed circuit board **13**, and the second and fourth shake correction coils **40***b*, **40***d* are disposed on the +Y side portion and the −Y side portion of the printed circuit board **13**. Optionally, the shake correction coils **40** are printed coils that are formed by film deposition and patterning. When the currents flow through the shake correction coils, the electromagnetic forces generated by the magnets and the shake correction coils drive the movable unit to move in the X axis direction and the Y axis direction relative to the base.

The lens actuator **100** further comprises a supporter **30** located between the magnet holder **21** and the base **11** for making the magnet holder **21** movably mounted on the base **11**. The supporter **30** may include four balls **32**. Each ball **32** has one part received in the mounting groove **215** of the magnet holder **21** and another part resting against the base **11** to movably support the magnet holder **21**. Alternatively, the supporter **30** may include four helical springs **33**. One end of each helical spring **33** is received in the blind hole **216** of the magnet holder **21** and another end of the helical spring **33** rests against the base **11** for elastically supporting the magnet holder **21**.

The focusing coils **24** are electrically connected to the printed circuit board **13** through the upper spring plate **23***b*, lower spring plate **23***a* and wires **31**. The shake correction coils **40** are electrically connected to the printed circuit board **13** while connected in series.

When the camera shake occurs while the shooting is performed by pressing a shutter push button, the electronic circuit using a magnetic-field sensor or the like that is separately provided in the electronic instrument detects the position of the movable unit. Then the electronic circuit moves the movable unit **20** in the X direction and the Y direction by controlling the currents flowing through shake correction coils **25**, thereby performing shake correction control.

When the swing of the optical axis occurs, the electronic circuit detects the position of the optical axis using a position sensor or the like that is separately provided in the electronic instrument. The electronic circuit moves the lens holder **22** moves along the optical axis direction by controlling the currents flowing through the focusing coils **24**, thereby performing swing correction control.

While the present invention has been described with reference to a specific embodiment, the description of the invention is illustrative and is not to be construed as limiting the invention. Various of modifications to the present invention can be made to the exemplary embodiment by those skilled in the art without departing from the true spirit and scope of the invention as defined by the appended claims.

What is claimed is:

1. A lens actuator, comprising:

a movable unit comprising,

a carrier defining an optical axis in a center thereof,

a plurality of focusing coils surrounding the carrier and spaced with each other, each of the focusing coils wound around an axis perpendicular to the optical axis and fixed on an outer surface of the carrier,

a plurality of magnets each opposite to one of the focusing coils in a direction perpendicular to the optical axis direction,

a holder fixing the magnets;

a plurality of shake correction coils each disposed below one of the magnets and opposite to the magnet in the optical axis direction;

a base fixing the shake correction coils;

a plurality of wires connecting the movable unit to the base; wherein

the carrier moves in the optical axis direction by an electromagnetic force generated between the focusing coils and the magnets, the movable unit moves in the direction perpendicular to the optical axis direction by another electromagnetic force generated between the shake correction coils and the magnets.

2. The lens actuator of claim **1**, wherein the focusing coils comprises a first focusing coil, a second focusing coil, a third focusing coil and a fourth focusing coil, the first and third focusing coils wound around a first axis perpendicular to the optical axis and fixed on the carrier in the first axis direction; and the second and fourth focusing coils wound around a second axis perpendicular to the optical axis and fixed on the carrier in the second axis direction; wherein the first axis is perpendicular to the second axis.

3. The lens actuator of claim **2** further comprising a printed circuit board mounted on the base and electronically connected with the focusing coils;

the shake correction coils are printed coils formed on the printed circuit board.

4. The lens actuator of claim **1** further comprising a supporter located between the movable unit and the base for movably mounting the movable unit on the base.

5. The lens actuator of claim **4**, wherein the supporter includes a plurality of balls for supporting the movable unit.

6. The lens actuator of claim **5**, wherein the movable unit has a plurality of mounting grooves in a bottom surface thereof for receiving the balls.

7. The lens actuator of claim **4**, wherein the supporter includes a plurality of helical springs for supporting the movable unit.

8. The lens actuator of claim **7**, wherein the movable unit has a plurality of blind holes in a bottom surface thereof for receiving the helical springs.

9. The lens actuator of claim **1**, wherein each magnet is divided into a first half part and a second half part, wherein the first and second half parts are such magnetized that magnetic poles on inner surfaces of the first and second half parts differ from each other, and such that magnetic poles on outer surfaces of the first and second half parts also differ from each other.

10. The lens actuator of claim **1**, wherein the carrier received in the holder includes a plurality of projections each protruding toward the holder from the outer surface of the carrier and corresponding to one of the focusing coils for engaging with the focusing coils.

11. A lens actuator comprising,

a housing comprising a base and a cover assembled with the base for forming a receiving space;

a movable unit received in the receiving space and comprising:

a magnet holder movably mounted on the base and defining a receiving hole,

a spring plate connected with the magnet holder,

a lens holder defining an optical axis and elastically suspended in the receiving hole by the spring plate,

a plurality of focusing coils surrounding the lens holder and spaced with each other, each of the focusing coils wound around an axis perpendicular to the optical axis, and attached on an outer surface of the lens holder;

a plurality of magnets mounted on the magnet holder and each opposite to one of the focusing coils in a direction perpendicular to the optical axis direction,

a plurality of shake correction coils fixed on the base and each positioned below one of the magnets and facing the magnet with a space therebetween;

a plurality of wires connected the magnet holder to the base; wherein, the lens holder moves in the optical axis direction by an electromagnetic force generated between the focusing coils and the magnets, the movable unit moves in the direction perpendicular to the optical axis direction by another electromagnetic force generated between the shake correction coils and the magnets.

12. The lens actuator of claim **11**, wherein the focusing coils comprise a first focusing coil, a second focusing coil, a third focusing coil and a fourth focusing coil, the first and third focusing coils wound around a first axis perpendicular to the optical axis and fixed on the lens holder in the first axis direction; and the second and fourth focusing coils wound around a second axis perpendicular to the optical axis and fixed on the lens holder in the second axis direction; wherein the first axis is perpendicular to the second axis.

13. The lens actuator of claim **12** further comprises a printed circuit board mounted on the base and electronically connected with the focusing coils;

the shake correction coils are printed coils formed on the printed circuit board.

14. The lens actuator of claim **11** further comprises a supporter located between the magnet holder and the base for movably mounting the movable unit on the base.

15. The lens actuator of claim **14**, wherein the supporter includes a plurality of balls for supporting the movable unit.

16. The lens actuator of claim **15**, wherein the movable unit has a plurality of mounting grooves in a bottom surface thereof for receiving the balls.

17. The lens actuator of claim **14**, wherein the supporter includes a plurality of helical springs for supporting the movable unit.

18. The lens actuator of claim **17**, wherein the movable unit has a plurality of blind holes in a bottom surface thereof for receiving the helical springs.

19. The lens actuator of claim **11**, wherein each magnet is divided into a first half part and a second half part, wherein the first and second half parts are such magnetized that magnetic poles on inner surfaces of the first and second half parts differ from each other, and such that magnetic poles on outer surfaces of the first and second half parts also differ from each other.

20. The lens actuator of claim **11**, wherein the lens holder received in the magnet holder includes a plurality of projections each protruding toward the magnet holder from an outer surface of the lens holder and corresponding to one of the focusing coils for engaging with the focusing coils.

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